A phase locked, fiber laser-based frequency comb: limit on optical linewidth*

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Abstract: A phase-locked fiber laser-based frequency comb is presented. Despite the broad linewidth of the measured carrier-envelope offset frequency, the linewidth of a single line near the center of the frequency comb is ≤ 6 kHz.

OCIS codes: (140.3510) Lasers, Fiber; (190.4370) Nonlinear Optics, Fibers; (120.3930) Metrological Instrumentation;

Recently, a phase-locked, all-fiber supercontinuum source has been developed for IR frequency metrology [1]. This source generates an octave-spanning supercontinuum [2] that is used to detect the comb offset frequency [3, 4]. Narrow comb linewidths would be an attractive feature of this source for precision metrology. In this work, an upper bound of the linewidth of a single line of the frequency comb near 1550 nm is determined to be ≤ 6 kHz.

Figure 1(a) depicts the supercontinuum source, which consisted of a passively mode-locked, Erbium-doped fiber laser (EDFL), a fiber amplifier, and a length of dispersion-flattened, highly nonlinear, dispersion-shifted fiber (HNLF). The supercontinuum spanned from 1100 nm to 2300 nm; the resulting frequency comb was 142.3 THz wide with a comb tooth separation of 49.8 MHz, which was the laser repetition rate. To stabilize the comb, both the repetition rate (f_r) and the offset frequency (f_0) were phased-locked to an RF source. The repetition rate was locked to a stable RF source using a piezoelectric (PZT) fiber stretcher in the EDFL cavity. The offset frequency was measured by mixing 1080 nm light with frequency-doubled 2160 nm light in an f-to-2f interferometer [3]. The resulting beat frequency generated an error signal that was fed back to the 980 nm pump power. The 1080 nm and 2160 nm portions of the supercontinuum are shown in Fig. 2 along with the corresponding offset beat.

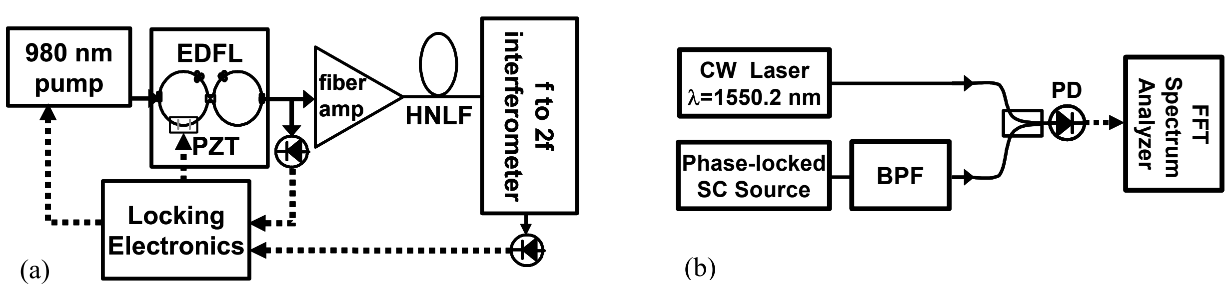
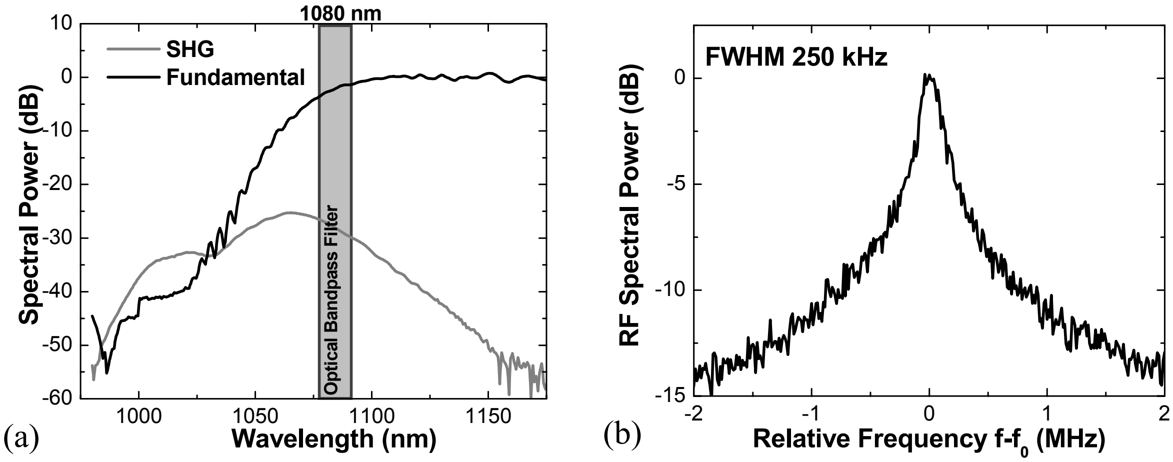


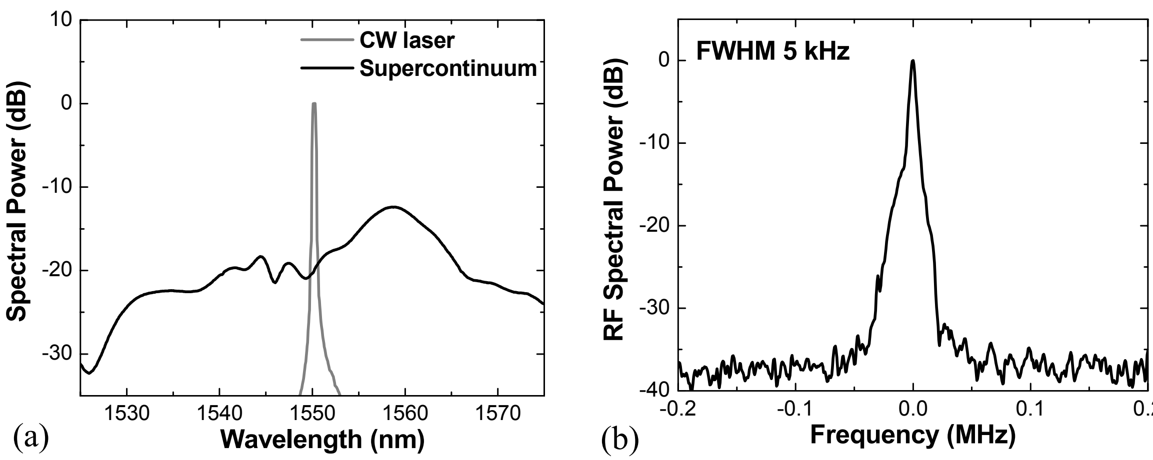
Fig 1. (a) The all fiber-based, phase-locked supercontinuum source. (b) Heterodyne beat experiment between the supercontinuum (SC) source and narrow linewidth cw laser at 1550.2 nm. PD: photodiode. BPF: bandpass filter. Solid lines denote optical paths and dashed lines denote electrical paths.



(a) (b)

Fig 2. (a) The 1080 nm and frequency doubled 2160 nm portion of the supercontinuum. (b) The corresponding f_0 beat has a 250 kHz full width at half-maximum (FWHM) measured with a resolution bandwidth of 30 kHz.

The broad 250 kHz linewidth of the f_0 beat indicates the presence of substantial noise on the edges of the supercontinuum. To measure an upper limit of the linewidth near the *center* of the supercontinuum, we used the setup of Fig. 1(b). A 2.5 nm portion of the unlocked supercontinuum was mixed with a narrow linewidth cw laser at 1550.2 nm (Fig. 3). The beat was produced by mixing the ~4×10^6 tooth of the supercontinuum frequency comb with the cw laser. The resulting linewidth was 5 ± 1 kHz FWHM. As a comparison, light directly from the fiber laser was mixed with the cw laser and the resulting beat exhibited a similar linewidth. This measurement represents an upper limit of the comb linewidth since the exact linewidth of the cw laser is currently unknown. Therefore, while supercontinuum generated by a fiber laser in a highly nonlinear optical fiber can suffer from significant phase noise (Fig. 2 and Ref. [5]), our result implies that the generated phase noise can be significantly smaller for the useful center region about 1550 nm.



(a) (b)

Fig. 3. (a) Spectral overlap of the unfiltered supercontinuum and the cw laser. (b) The resulting averaged RF beat using an FFT spectrum analyzer with a 1 ms acquisition time (corresponding to a 4 kHz resolution bandwidth).

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